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TECHNICAL REPORT

ON THE DETECTION OF A 40 TO 50 DAY
OSCILLATION IN SEA SURFACE TEMPERATURE
ALONG THE CENTRAL CALIFORNIA COAST

by

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Previous studies of the tropical troposphere indicate the presence of a 40 to 50 day oscillation in zonal winds. Spectral analysis of sea surface temperature reveals an increase in variance between 40 and 50 days along the California coast as far south as Santa Barbara (34.4N) and at least as far north as Pt. Arena (39N). Increases in the amplitude of this oscillation at 36N generally coincide with local El Nino warming episodes. It is suggested that the 40 to 50 day oscillation in sea surface temperature off central California may be related to the 40 to 50 day oscillation in the tropical troposphere through

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ON THE DETECTION OF A 40 TO 50 DAY OSCILLATION IN SEA SURFACE TEMPERATURE ALONG THE CENTRAL CALIFORNIA COAST

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Abstract. Previous studies of the tropical troposphere indicate the presence of a 40 to 50 day oscillation in zonal winds. Spectral analysis of sea surface temperature reveals an increase in variance between 40 and 50 days along the California coast as far south as Santa Barbara (34.4N) and at least as far north as Pt. Arena (39N). Increases in the amplitude of this oscillation at 36N generally coincide with local El Nino warming episodes. It is suggested that the 40 to 50 day oscillation in sea surface temperature off central California may be related to the 40 to 50 day oscillation in the tropical troposphere through atmospheric teleconnections between the tropics and mid-latitudes.

Introduction

Numerous observations of oscillations in atmospheric properties with periods in the range of 30 to 60 days have been reported over the past 14 years. Madden and Julian (1971) detected a 40 to 50 day oscillation in zonal winds and pressure in the lower troposphere over Canton Island. These oscillations were subsequently attributed to convective processes on a global scale and also were observed to propagate eastward and poleward in the tropical Indian and Pacific Oceans (Madden and Julian, 1972). Yasunari (1979; 1980) observed fluctuations in cloudiness over the tropical Indian Ocean with periods ranging from 30 to 40 days. A peak in zonal winds at 850 mb with

periods between 30 and 50 days was observed during the summer of 1979 in the Arabian Sea (Krishnamurti and Subrahmanyam, 1982). The relative angular momentum at levels below 100 mb contains quasi-periodic variations with periods of 40 to 50 days (Rosen and Salstein, 1983). Oscillations in the 35 to 80 day range were found in satellite-derived outgoing longwave radiation during Northern Hemisphere winters (Weickmann, 1983). Finally, 40 to 60 day oscillations in surface winds occurred over the Western Indian Ocean during 1976 and 1979 (Mertz and Mysak, 1984).

Recently, variations in sea level with an approximate period of 45 days were found at five locations along the South American coast between 4N and 12S (Enfield and Lukas, 1984). These variations in sea level were traced to wind forcing further east along the equator.

The 40 to 50 day oscillation is strongly correlated with variations in the polar component of the angular momentum of the atmosphere (Langley et al., 1981). The exchange of momentum between the earth's atmosphere and its surface is important in determining both the structure of atmospheric flow and the dynamics of the earth's rotation (ibid). The 40 to 50 day oscillation also resembles, and may even be an important factor in causing, El Nino episodes (Kerr, 1984). Such a resemblance between certain attributes of the 40 to 50 day oscillation and those associated with El Ninos was implied earlier by Madden and Julian (1972). More recently Lau and Chan (1983) have clearly emphasized the similarities in these two phenomena.

The purpose of this paper is to document the existence of a 40 to 50 day oscillation in sea surface temperature along the central California coast. A description of the data used in this study is followed by a presentation of spectra that reveal the presence of this oscillation. Finally, we conclude with a brief discussion on the origin of the observed oscillations.

The Data

Daily sea surface temperatures at five locations along the central California coast are examined (Fig. 1). The locations and the periods spanned by these series are indicated below (Table 1).

Table 1. Sea-Surface Temperature Locations and Dates

Location	Dates
Point Arena	1 June 1979 to 1 Jan 1983
Farallon Islands	1 March 1971 to 1 March 1983
Pacific Grove	1 Jan 1919 to 1 Jan 1982*
Granite Canyon	1 March 1971 to 1 March 1985
Santa Barbara	1 March 1971 to 26 Sept 1977

*The year 1940 is missing.

The selection of particular locations for sea surface temperature was based on three factors, first, on the representativeness of the site, second, on the available length of data, and third, on the completeness of the record. These data are reported to be accurate to $\pm$0.2C (SIO Ref. 81-30). Occasional missing values were filled by linear interpolation (gaps usually accounted for less than 2% of the entire record). Preliminary analysis of these data indicates that variability on time scales of a few days (the "sudden" spring transition to coastal upwelling) to several years (El Nino influence) was important (Breaker and Mooers, 1985). Contrary to the results of List and Koh (1976), who found tidal aliasing (and/or the spring and neap tides) to be present at several coastal locations along California, we did not find significant variance at the predicted periods (14.3 and/or 14.7 days).

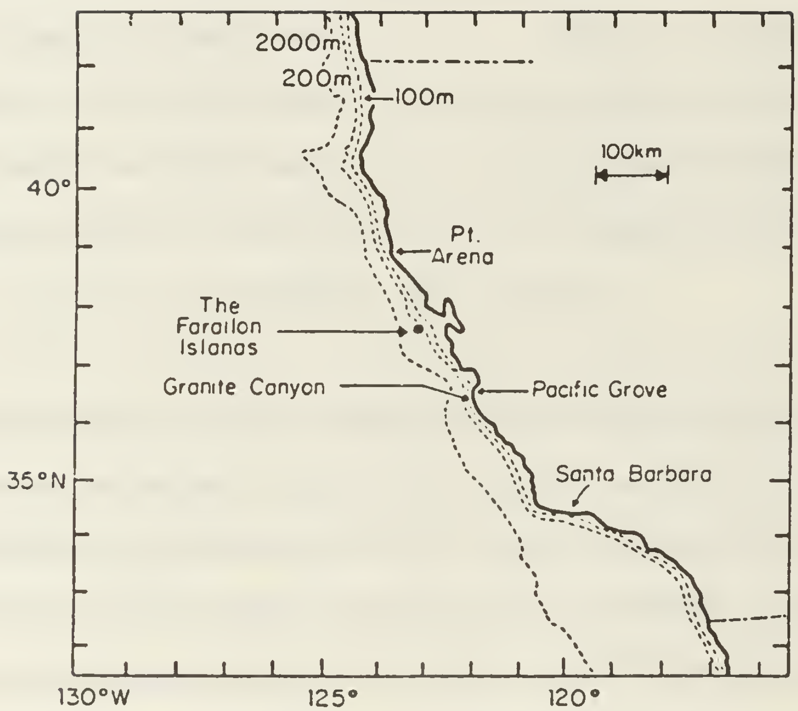

Fig. 1. Locations along the California coast where sea surface temperatures were acquired.

Analysis

Periodograms of sea surface temperature at four locations along the California coast between Santa Barbara (34.4N) and Pt. Arena (39N) were calculated (Fig. 2). Slight smoothing was applied yielding spectral estimates with approximately 18 degrees of freedom. No detrending or prewhitening was applied to the data prior to these calculations. The annual cycle and its second harmonic (6 months) are evident at each location. Spectral peaks at periods between 46 and 48 days occur at each location. In each case, these peaks are at least 2 to 3 dB higher in amplitude than adjacent spectral estimates. Periodograms for three locations south of Santa Barbara [Pt. Dume (34N), Los Angeles (33.8N), and San Diego (32.8N)] did not indicate the presence of the 40 to 50 day oscillation, however.

To examine the occurrence of the spectral peak at approximately 47 days in greater detail, daily sea surface temperatures at Pacific Grove extending from 1919 to 1982 were also subjected to periodogram analysis. Raw periodograms were initially calculated from 10 six-year segments of the data. The results were averaged producing a mean spectrum with each spectral estimate having about 60 degrees of freedom (Fig. 3). In addition to the primary spectral peak corresponding to the annual cycle, a clearly defined peak also occurs at 46.8 days. Because the underlying spectrum is not white, it is not possible to estimate the significance of this peak at any given level of confidence. However, the fact that this increase in variance around 47 days was observed in each of the periodograms used to calculate the mean spectrum shown in Fig. 3, provides strong evidence for both its uniqueness and its persistence. Although this mean spectrum implies a significant periodicity at approximately 47 days, individual spectra calculated for successive two-year intervals over the entire record indicate that

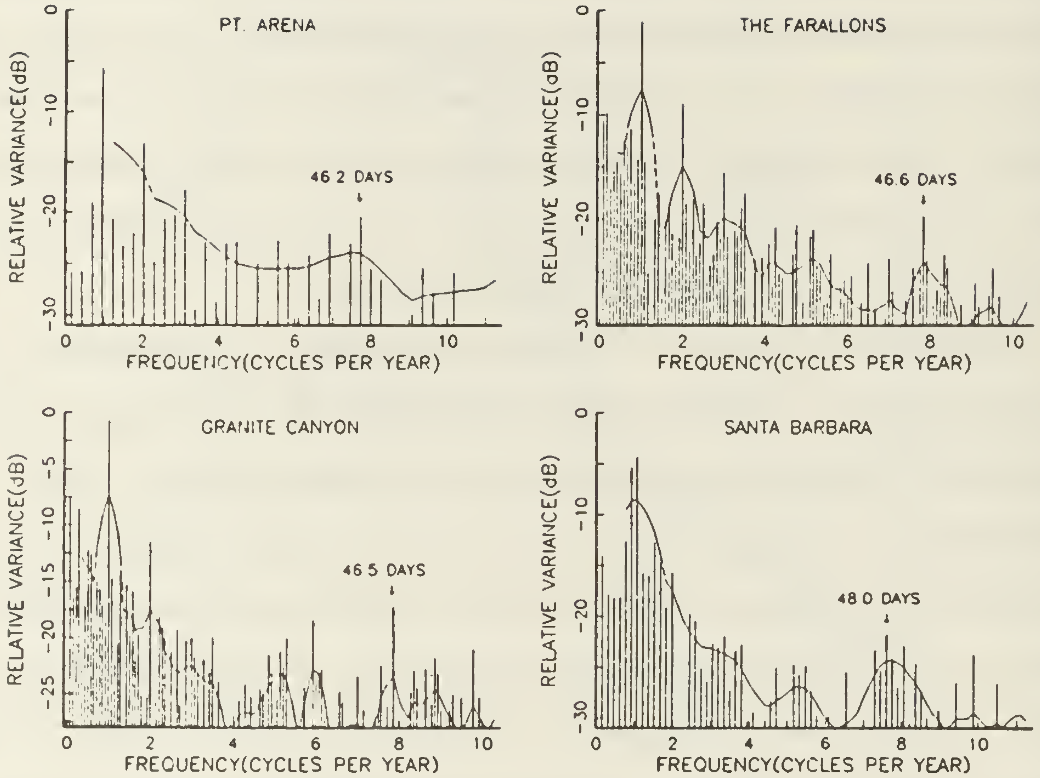

Fig. 2. Raw and slightly smoothed partial periodograms (out to 10 cycles per year) of sea surface temperature at Pt. Arena, the Farallon Islands, Granite Canyon and Santa Barbara. The vertical axis is 10 Log_{10} of the relative variance, or decibels (dB).

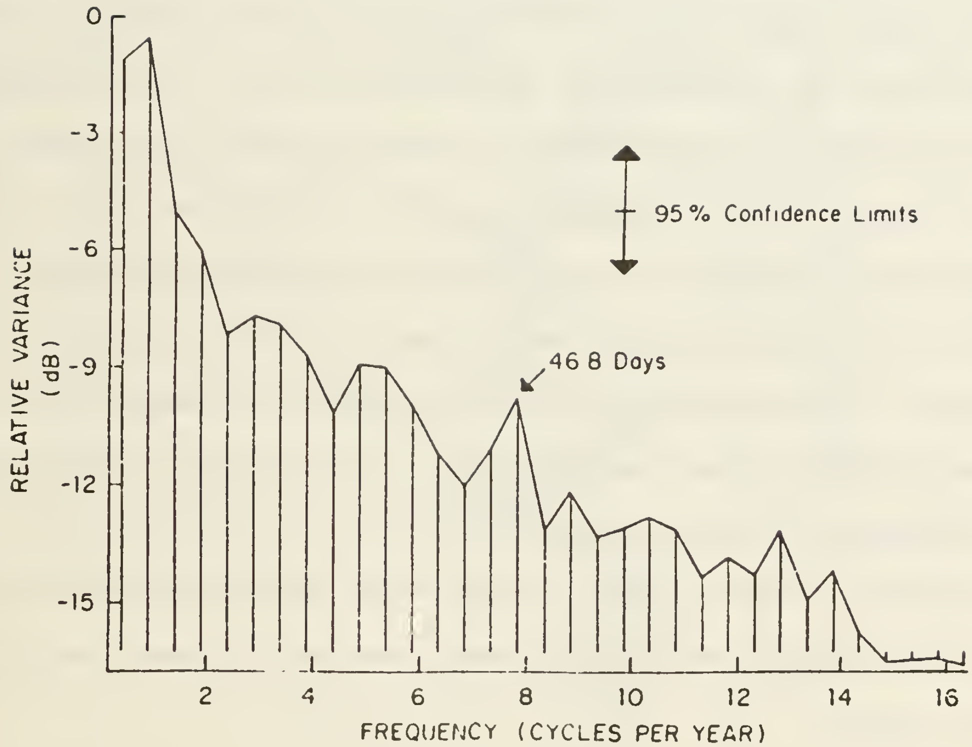

Fig. 3. A smoothed periodogram of daily sea surface temperature at Pacific Grove with periods ranging from 3 years to 22 days. Periodograms for ten 6-year segments between 1919 and 1982 were averaged. Subsequent smoothing resulted in spectral estimates with about 60 degrees of freedom.

this oscillation is not fixed in frequency but varies within approximately ± 10% of the central value. Variations in frequency about the central value tended to occur during periods when the amplitude of the ~47 day oscillation was relatively low.

Indications of the 40 to 50 day oscillation can also be seen in selected segments of the raw data. One segment, taken between 1 March 1973 and 1 March 1974 at Pacific Grove, indicates the presence of this oscillation (Fig. 4). The peak-to-peak amplitude of the oscillation is of the order of 1 to 2C.

Sea surface temperatures at Granite Canyon were band-pass filtered with high and low half-amplitude cut-off frequencies of 30^{-1} (30 days) and 70^{-1} (70 days) cycles per day, respectively (upper panel, Fig. 5). The low-passed version of this series clearly shows the influence of El Nino warming events along the central California coast during this period (lower panel, Fig. 5). The major warming episodes of 1972-73, 1976-77 and 1982-83 are easily identified. Even the relatively weak episode in 1979-80 (Donguy et al., 1982) can be seen. Both the amplitude and the period (and/or phase) of the band-passed filtered signal vary with time. Of particular interest are the higher amplitudes that occur in 1972, 1975, 1979 and 1982-83. These increases in the amplitude of the ~47 day cycle generally coincide with the major and minor El Nino episodes that have occurred along the California coast during the past 15 years.

Discussion

Oscillations in sea surface temperature have been detected along the central California coast in the range of 40 to 50 days. These oscillations may be related to the 40 to 50 day oscillations in atmospheric properties that occur in the tropical troposphere. According to Anderson and Rosen (1983), the 40 to 50 day oscillations in the tropical troposphere are coherently connected to mid-latitudes in the Northern Hemisphere. The tropical

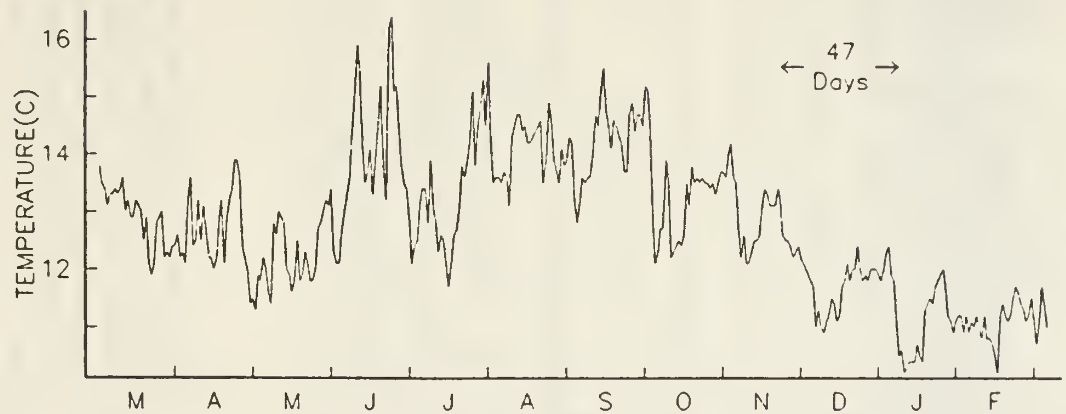

Fig.4. Daily sea surface temperatures at Pacific Grove from 1 March 1973 to 1 March 1974

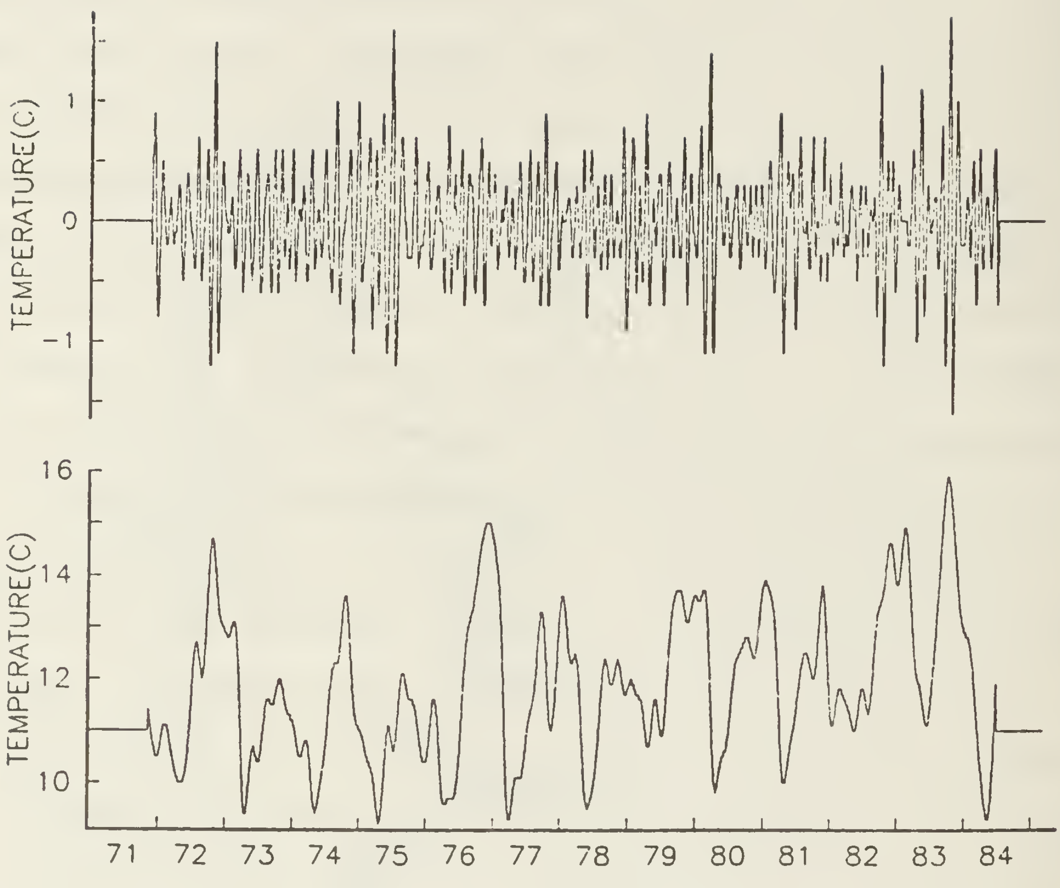

Fig.5. Band-pass filtered sea-surface temperature time series at Granite Canyon from 11 November 1971 to 25 June 1984 (upper panel). The high and low half-amplitude cut-off frequencies of the band-pass filter correspond to periods of approximately 30 and 70 days, respectively. The low-passed version of this series is shown in the lower panel.

oscillations appear to propagate poleward and downward with linkages to a mid-latitude component centered near 40N (ibid). Thus, the observed variations in sea-surface temperature may arise from local atmospheric forcing whose origin can be traced back to the tropics.

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